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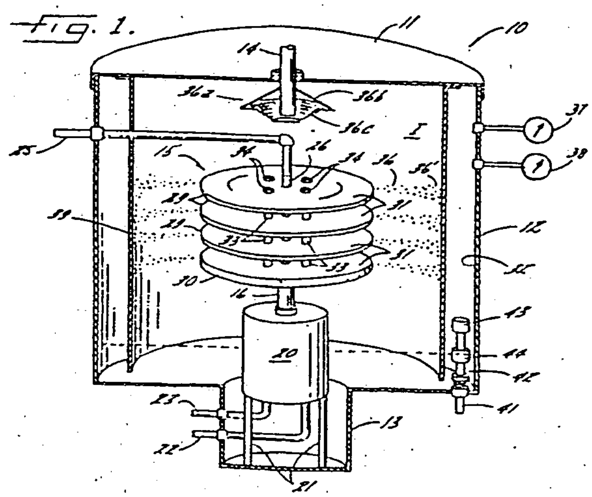
(54) Fluid purifier.

(57) The disclosure describes a device for separating a volatile contaminant from a contaminated fluid. The device comprises a vacuum chamber (10) having an internal space (I) that may be at least partially evacuated, a rotating plate arrangement (30) disposed within the vacuum chamber (10), means (25) for introducing the contaminated fluid on to the surface of the plate arrangement, whereby small droplets (36) of the contaminated fluid are centrifugally dispersed from the edge of the rotating plate arrangement (30), said droplets (36) having sufficient residence time within the evacuated space (I) to permit at least a portion of the contaminant to be released, and means (39) for coalescing the small droplets.

Fig. 1.



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FLUID PURIFIER

The present invention relates to a device for separating a fraction of a volatile contaminant from a contaminated liquid. The invention also relates to a method and to a system for purifying a contaminated fluid.

Fluids frequently become contaminated during use and must be purified before they can be recycled. For example, lubricants, hydraulic fluids, transformer oils, and cutting fluids often become contaminated with water, cleaning solvents, or other volatile contaminants which must be separated from the fluids before the fluids can be reused.

Fluid purifiers have been previously based on the use of heat or vacuum or both to separate a volatile contaminant from a fluid. One problem with previous fluid purifiers is to provide sufficient purification in a single pass through the purifier without harming the fluid itself. Purifiers with harsh processing conditions, such as excessive heat or excessive vacuum, may provide sufficient purification in a single pass, but they often have destructive effects on the fluid being purified. For example, the fluid can be seriously altered through the loss of low boiling point components, removal of additives, or oxidation or charring of the fluid.

Purifiers with milder processing conditions, such as lower temperature or lower vacuum, may not harm the fluid being purified, but they often provide only partial purification in a single pass. The fluid must

be pumped through the purifier many times for sufficient purification. This multi-pass approach substantially increases the amount of energy and time needed to purify the contaminated fluid.

One problem of previous fluid purifiers based on the use of a vacuum is producing a large enough surface area for a given volume of fluid to allow sufficient release of the contaminant. There is less resistance to the release of volatile contaminants at or near the surface of the fluid than within the body of the fluid. Insufficient surface area results in only partial purification, again making it necessary to pump the fluid through the purifier many times before the fluid is sufficiently purified.

Another problem with previous vacuum purifiers is that their performance varies substantially with the viscosity of the contaminated fluid. These purifiers usually use some medium, such as a downward flow column, to form a thin film of the contaminated fluid which increases the surface area of the fluid. If the fluid is viscous, however, it forms a thick film. The release of volatile contaminants from the body of the thick film is a much slower process which increases the time required to purify the fluid.

Specific problems to be overcome include providing a fluid purifier: (1) that sufficiently purifies the fluid in a single pass through the purifier without significantly deteriorating or altering the fluid itself; (2) that produces a large surface area for a given volume of fluid; (3) that provides essentially constant performance regardless of fluid viscosity; and

(4) that requires a minimum amount of energy and time to purify the fluid.

These problems are solved by the provision of a device that comprises a chamber, means for dispersing the fluid into droplets including at least one rotary plate disposed within the chamber, means for introducing the fluid onto a surface of the plate, and means spaced from the plate for coalescing the droplets, the distance between the edge of the plate and the coalescing means providing a sufficient droplet residence time to permit the fraction of the volatile contaminant to be separated from the fluid as each droplet travels between the edge of the plate and the coalescing means.

The size of each droplet is largely independent of the viscosity of the fluid, and each droplet has a large surface area in relation to its volume. Consequently, the volatile contaminant is rapidly and thoroughly released from each droplet in the form of a vapour, leaving behind a purified droplet. The vapourized volatile contaminant may be removed from the chamber by a vacuum pump. For convenience, the chamber may be sized such that the droplets impinge against the interior surface of the chamber to effect coalescence.

The present invention also encompasses an integrated purification system for removing particulates as well as volatile contaminants from a contaminated fluid. The purifying system comprises at least one pump for moving the fluid through the system, an initial filter for removing particulates, and a fluid purifier having a rotating plate for removing volatile contaminants

from the fluid.

The present invention achieves each of the objects stated above. Further, it provides a fluid purifier that purifies a wide spectrum of fluids. This fluid purifier is small and lightweight yet has a large purifying capacity and operates with a high degree of reliability.

The invention will now be described, by way of example, with reference to the accompanying diagrammatic drawings, in which:

FIG. 1 is a part-sectional perspective view of a fluid purifier device embodying the present invention,

FIG. 2 is a partial elevation view of a plate assembly of the fluid purifier device of FIG.1;

FIG. 3 is a sectional elevation view, to an enlarged scale, of the centre portion of one of the discs in the plate assembly of FIG. 2; and

FIG. 4 is a block diagram of a fluid-purifying system incorporating the fluid purifier device of FIG.1.

As shown in FIG. 1, the fluid purifier 10 comprises a vacuum chamber 11 which includes a casing 12 and a well 13. The vacuum chamber 11 defines an evacuated space I. A vacuum pump (not shown in FIG.1), which communicates with the vacuum chamber 11 via an exhaust port 14, establishes and maintains the vacuum.

With the casing 12, a plate assembly 15 is mounted for

rotation by the drive shaft 16 of a hydraulic motor 20. The hydraulic motor 20 is mounted on supports 21 which, in turn, are mounted on the vacuum chamber 11 at the well 13.

Alternatively, the plate assembly 15 could be rotated by an electric or pneumatic motor disposed either inside or outside the vacuum chamber 11. A hydraulic motor 20 disposed within the vacuum chamber 11 is particularly advantageous, however, because no vacuum-tight seal at a rotating shaft is required and because the hydraulic motor 20 is highly reliable and efficient.

In operation, a suitable hydraulic fluid is pumped into a feed port 22 by a feed pump (not shown in FIG.1), driving the hydraulic motor 20 and thereby rotating the plate assembly 15. The hydraulic fluid then exits the hydraulic motor 20 through a fluid port 23. The contaminated fluid enters the casing 12 through an inlet port 25, where it is fed to the rotating plate assembly 15 by a flow distributor 26. In one embodiment of the invention, the contaminated fluid serves as the hydraulic fluid, i.e., the contaminated fluid is first pumped into the hydraulic motor 20 via the feed port 22 and, upon exiting through the fluid port 23, is fed directly into the casing 12 through the inlet port 25. In this embodiment, the speed of rotation of the plate assembly 15 is governed by the feed pump, and the motor speed is matched to the feed rate to provide a constant level of performance. A speed of approximately 6150 rpm should give satisfactory results.

As shown in FIG. 2, the plate assembly 15 comprises a stack of discs 29 supported by a plate 30 which is mounted on the drive shaft 16. For example, the stack may comprise as many as twenty-four or more discs 29 supported by a single plate 30. A single disc only may be provided in addition to the plate 30. The discs 29 and the plate 30 may be fashioned from any of a variety of materials, provided the materials can withstand the rotational speeds contemplated. Nylon and aluminium are examples of materials which might be used. The discs 29 are stacked one on another with their centres aligned, the line formed by their centres being perpendicular to the top surfaces 31 of the discs 29, and the top surface 31 of each disc 29 defines a plane which intersects the wall 32 of the vacuum chamber 11. The discs 29 are separated from one another and from the plate 30 by hollow spacers 33. The plate assembly 15 is secured together by nuts 34 and bolts 35 running through the discs 29, the plate 30 and the hollow spacers 33. The flow distributor 26 extends through the centre of each disc 29 aligned with the drive shaft 16 and with an imaginary line passing through and perpendicular to each disc.

As shown in FIG. 3, at each disc 29, a portion P of the flow F of contaminated fluid feeds through the flow distributor 26 and on to the top surface 31 of each disc 29. The flow may also be directed on the undersurface of each disc. The flow distributor 26 may, for example, comprise a rod-like or tubular member formed of a porous material. Alternatively, a tube may be used having apertures graded in number and/or size so that approximately the same amount of liquid is delivered to each disc and the plate. In systems where

the contaminated fluid is filtered through a relatively fine pre-filter (e.g., of the order of 10-20 micrometers), a relatively coarse material may be employed for the flow distributor 26. Specifically, a porous material having a 30-plus mesh should provide satisfactory results. Due to the centrifugal effects of each rotating disc 29, contaminated fluid which feeds on to the surface 31 of a disc 29 migrates to the edge of the disc 29 and is then sprayed outwardly in the form of very small droplets 36, as shown in FIG. 1. In other words the liquid is atomized. The energy required to produce the droplets 36 is fixed at a low value, approximately that required to rotate the free-spinning plate assembly 15.

Generally, the size of each droplet 36 emitted from the edge of each disc 29 (and the plate 30) will lie within a range distributed about a theoretical size which can be determined from the following equation:

$$d = \frac{K}{V(D\rho/T)^{1/2}}$$

where d equals the theoretical droplet diameter, V equals the disc rotational velocity, D equals the disc diameter, ρ equals the fluid density, T equals the fluid surface tension and K is an empirical constant approximately equal to 4.5 when the other variables are expressed in cgs units and V is in rpm. For example, if a fluid having a density of one gram per cubic centimeter and a surface tension of ten dynes per centimeter is introduced onto the surface of an 8-inch (i.e., 20-centimeter) disc rotating at 6150 rpm, droplets emitted from the edge of the disc are expected

to have diameters distributed about a theoretical droplet diameter of approximately five micrometers.

As seen from the above equation, the size of each droplet 36 generated by each rotating disc 29, and therefore the surface area of the droplet 36, is largely independent of fluid viscosity, which can vary from fluid to fluid by several orders of magnitude. Rather, the droplet size depends on fluid density and surface tension, which are normally within a narrow band of values. Thus, a wide spectrum of fluids may be dispersed in the form of very small droplets, and while the performance of the purifier 10 may vary with viscosity of the fluid being processed, the range of performance is expected to be relatively limited and remain high even for relatively viscous fluids. Generally, fluid purifiers 10 embodying the present invention are constructed and operated so they define a theoretical droplet diameter preferably of about 40 micrometers or less and most preferably within the range from about 20 micrometers to about 2.5 micrometers. It is expected that the diameters of droplets actually generated will be distributed about the theoretical droplet diameter.

The generation of droplets will deviate from that described above when the rate that the contaminated fluid is supplied to each disc 29 exceeds a certain limit. This limiting flow rate for each disc 29 has been found to be:

$$Q(max) = 4\pi^2 R^2 Vd = \frac{4\pi^2 RK}{(2R\rho/T)^{1/2}}$$

where R equals the disc radius and d equals the droplet diameter as given above. In general, the preferred flow rate is maintained at 10% to 25% of Q(max).

As the droplets 36 of contaminated fluid are formed and discharged from the edge of the rotating disc 29 toward the chamber wall 32, the volatile contaminant is released from each droplet 36 into the evacuated space I, leaving behind a purified droplet 36'. Generally, the majority of the resistance to the release of the volatile contaminant from the contaminated fluid occurs within the volume of the fluid. However, the very small droplets 36 generated by the rotating disc 29 have very large surface area-to-volume ratios. Consequently, the diffusion distance within the droplet 36 is very small and the resistance to release is minimized. The volatile contaminants flash from the droplet 36 very rapidly and thoroughly, necessitating a very short residence time for the droplet 36 to attain a substantial degree of purification and thereby allowing fluids to be purified in a single pass. For example, for a five micrometer droplet 36 discharged from the disc 29 at a velocity of about 6400 centimeters per second (i.e., the linear velocity at the edge of the above suggested 8-inch (i.e., 20-centimeter) disc rotating at 6150 rpm) in a vacuum chamber 11 having an inside diameter of about 60 centimeters, the resulting residence time of approximately four milliseconds is sufficient to allow a high degree of purification. This short residence time, coupled with small disc size, makes possible a small, compact design for the purifier 10, e.g., a purifier only 60 cm in diameter.

To facilitate the release of the contaminant, the purifier 10 operates at a high vacuum, but the fluid may be maintained at a temperature only slightly higher than the ambient temperature. For example, a vacuum of approximately 22 inches (i.e., 55 centimeters) of mercury and a contaminated fluid temperature of approximately 130 degrees F. (i.e., 55 degrees C.) is expected to provide very satisfactory results. Chamber vacuum and temperature gauges 37, 38 monitor the vacuum and temperature, respectively. The high vacuum does not significantly deteriorate or alter the fluid itself because of the short residence time of the fluid within the purifier 10. Single-pass purification and the use of little heat reduce the amount of energy required to purify the fluid.

After the volatile contaminant has been released from the droplet 36, the vaporized contaminant is drawn from the vacuum chamber 11 through the exhaust port 14 by the vacuum pump (not shown in FIG. 1). An oil mist baffle assembly 36a comprising a hood 36b and a screen 36b covers the exhaust port 14. As the vaporized contaminant, or any other gas within the vacuum chamber 11, is withdrawn through the exhaust port 14, the screen 36c filters any oil mist from the gas. A 60 mesh screen should provide satisfactory results.

The purified droplets 36' impact a removable sleeve 39 disposed between the plate assembly 15 and the chamber wall 32. Since the removable sleeve 39 reduces the effective inside diameter of the vacuum chamber 11, it reduces the residence time of the droplets 36, 36'. A series of removable sleeves having progressively larger diameters may be provided which allow

progressively larger residence times up to a maximum residence time defined by the chamber wall 32.

Upon impact, the purified droplets 36' coalesce as a purified fluid. Since the droplets 36' have a large surface tension relative to their available kinetic energy, they coalesce against the removable sleeve 39 rather than shatter to create a secondary fluid aerosol. The purified fluid drains down the removable sleeve 39 and collects in the lower portion of the vacuum chamber 11. The purified fluid is drained from the vacuum chamber 11 through a drain port 41 by means of a return pump (not shown in FIG. 1) which is controlled by a level switch 42 located at the bottom of the casing 12. The level switch 42 comprises a high-level indicator 43 that activates the return pump and a low-level indicator 44 that deactivates the return pump. The length of time the fluid is within the vacuum chamber 11 is short. This short residence time, coupled with single-pass purification, results in a substantially reduced purification time and increased capacity.

The fluid purifier 10 of FIG. 1 can be readily incorporated in an integrated fluid purifying system that removes particulates as well as volatile contaminants. As shown in FIG. 4, the fluid-purifying system comprises a hydraulic fluid drive system 45, a contaminated fluid feed system 46, a vacuum maintenance system 47, and a purified fluid removal system 48 in addition to the fluid purifier 10. The hydraulic motor 20 of this embodiment of the fluid purifier 10 is driven by a separate hydraulic fluid supplied by the hydraulic fluid drive system 45. A hydraulic fluid

feed pump 49 circulates the hydraulic fluid between a hydraulic fluid reservoir 50 and the hydraulic motor 20 with the hydraulic fluid entering the fluid purifier at the feed port 22 and exiting at the fluid port 23.

The contaminated fluid is warmed and fed to the fluid purifier 10 by the contaminated fluid feed system 46. A circulation pump 55 circulates the contaminated fluid between a contaminated fluid reservoir 56 and a heater 60 which maintains the contaminated fluid at a temperature only slightly above the ambient temperature, as monitored by a reservoir temperature gauge 61. The contaminated fluid is drawn from the contaminated fluid reservoir 56 to the fluid purifier 10 by the vacuum in the fluid purifier 10 or by an optional feed pump 62. En route, the contaminated fluid passes through a ball valve 63 and an initial particulate filter 64 which removes most of the particulates in the contaminated fluid. From the initial particulate filter 64, the contaminated fluid is drawn through a needle valve 65, past a fluid inlet temperature gauge 66, and into the fluid purifier 10 through the feed port 25, where the volatile contaminant is separated from the contaminated fluid as previously described.

The vacuum maintenance system 47 removes the vapourized volatile contaminant from the fluid purifier 10 in addition to maintaining the vacuum. A vacuum pump 70 draws the gases in the fluid purifier 10, including the vapourized volatile contaminant, through the exhaust port 14, past a gas outlet temperature gauge 71, and through a gas-flow orifice plate 72 which monitors the gas-flow. Since this gas may also contain droplets of

the fluid being purified, the gas is also drawn through an oil trap 73 and a coalescing filter 74 before being exhausted through a silencer 75. A vacuum relief valve 76 permits relief of the vacuum if, for example, access within the fluid purifier 10 is desired.

The purified fluid removal system 48 includes a return pump 80 which is controlled by the level switch 42 in the fluid purifier 10. When activated, the return pump 80 pumps the purified fluid from the fluid purifier 10 through the drain port 41, past a discharge fluid temperature gauge 81, and through a check valve 82 which prevents back flow into the fluid purifier 10. From the check valve 82, the purified fluid is pumped through a final particulate filter 83 and into a purified fluid reservoir 84.

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CLAIMS

1. A device for separating a fraction of a volatile contaminant from a contaminated fluid, characterized in that the device comprises a chamber (10), means (15) for dispersing the fluid into droplets (36) including at least one rotary plate (30) disposed within the chamber (10), means (25) for introducing the fluid on to a surface (31) of the plate, and means (39) spaced from the plate for coalescing the droplets, the distance between the edge of the plate and the coalescing means (39) providing a sufficient droplet residence time to permit the fraction of the volatile contaminant to be separated from the fluid as each droplet travels between the edge of the plate and the coalescing means.

2. A device according to claim 1, comprising means (47) for applying a reduced pressure to said chamber (10).

3. A device according to claim 1 or claim 2, characterized by a stack of discs (29) spaced from one another and mounted above said plate (30), the centres of the discs lying on a line perpendicular to the surface of each disc, the introducing means (25) serving additionally for depositing the fluid on at least one surface (31) of each disc.

4. A device according to claim 3, characterized in that the depositing means (14) comprises a flow distributor (26) disposed coaxially with the perpendicular line.

5. A device according to any one of claims 1 to 4, characterized in that the plate serves to produce droplets of a size of about 40 micrometers or less.

6. A device according to any one of claims 1 to 5, characterized by means for changing the distance between the edge of the plate (50) and the coalescing means (39).

7. A device according to any one of claims 1 to 6, characterized by means (42) disposed within the chamber (10) for collecting the purified fluid, means (48) communicating with the collecting means for removing the purified fluid from the chamber (10), and means (47) communicating with the chamber for drawing the released contaminant from the vacuum chamber.

8. A device according to any one of claims 1 to 7, characterized by a motor (20) coupled to the plate (30).

9. A device according to claim 8, characterized in that the motor is a hydraulic motor (20) mounted within the chamber (10).

10. A device according to claim 9, characterized in that said hydraulic motor is connected to the flow of the contaminated fluid upstream of the introducing means (14).

11. A device according to claim 1, characterized by one disc (29) mounted for rotation within the chamber (10), the introducing means (15) including inlet means for receiving a flow of contaminated fluid into the

chamber and means (26) for distributing first and second portions of the fluid on to the plate and the disc, respectively.

12. A device according to claim 11, characterized in that the disc (29) is disposed in a spaced parallel relationship with the plate (30) and the centres of the disc and the plate lie on a line perpendicular to a plane defined by each and characterized in that the distributing means comprises a flow distributor (26) disposed coaxially with the perpendicular line.

13. A method of separating a fraction of a volatile contaminant from a contaminated fluid, said method comprising the steps of providing a space (I), rotating a plate (30) disposed within the space (I), introducing the contaminated fluid on to the surface (31) of the rotating plate (30), whereby droplets (36) of the contaminated fluid are centrifugally sprayed from the edge of the plate, and coalescing the small droplets against a surface (39) disposed within the space (I), the edge of the rotating plate (30) being spaced a distance from the coalescing surface sufficient to yield a droplet residence time within the space (I) that permits the fraction of the volatile contaminant to be separated from the contaminated fluid as each droplet travels between the edge of the rotating plate and the coalescing surface, and collecting the purified fluid.

14. A method according to claim 13, characterized in that the space (I) is at least partially evacuated.

15. A system for purifying a contaminated fluid

containing particulates and volatile contaminants, said system being characterized by means (46) for moving the fluid through the system; an initial filter (64) for removing at least a portion of the particulates from the contaminated fluid; means (10) for separating a fraction of the volatile contaminant from the contaminated fluid, said separating means being located downstream from the filter (64) and including a chamber (I) having an internal surface, at least one plate (30) mounted for rotation within the chamber (I), means (25, 26) for introducing the contaminated fluid on to a surface of the plate, means (20) for rotating the plate whereby droplets (36) of the contaminated fluid are centrifugally thrown from the edge of the plate toward said internal surface, the distance between the edge of the plate and the internal surface providing a sufficient droplet residence time to permit the fraction of the volatile contaminant to be separated from the contaminated fluid as each droplet travels between the edge of the plate and the internal surface, means (39) for coalescing the droplets, and means (42) for collecting the purified fluid; means (41, 48) for removing the purified fluid from the chamber (I); and exhaust means (14, 47) for venting the released volatile contaminant from the vacuum chamber (I) including a coalescing filter (74) in communication with the exhaust means.

16. A system according to claim 15, characterized in that the removing means (41, 48) includes a final filter (83) for removing additional particulates.

17. A system according to claim 15 or claim 16, characterized by means (60) for heating the

contaminated fluid.

18. A system according to claim 15, 16 or 17, comprising means for applying at least a partial vacuum to said chamber.

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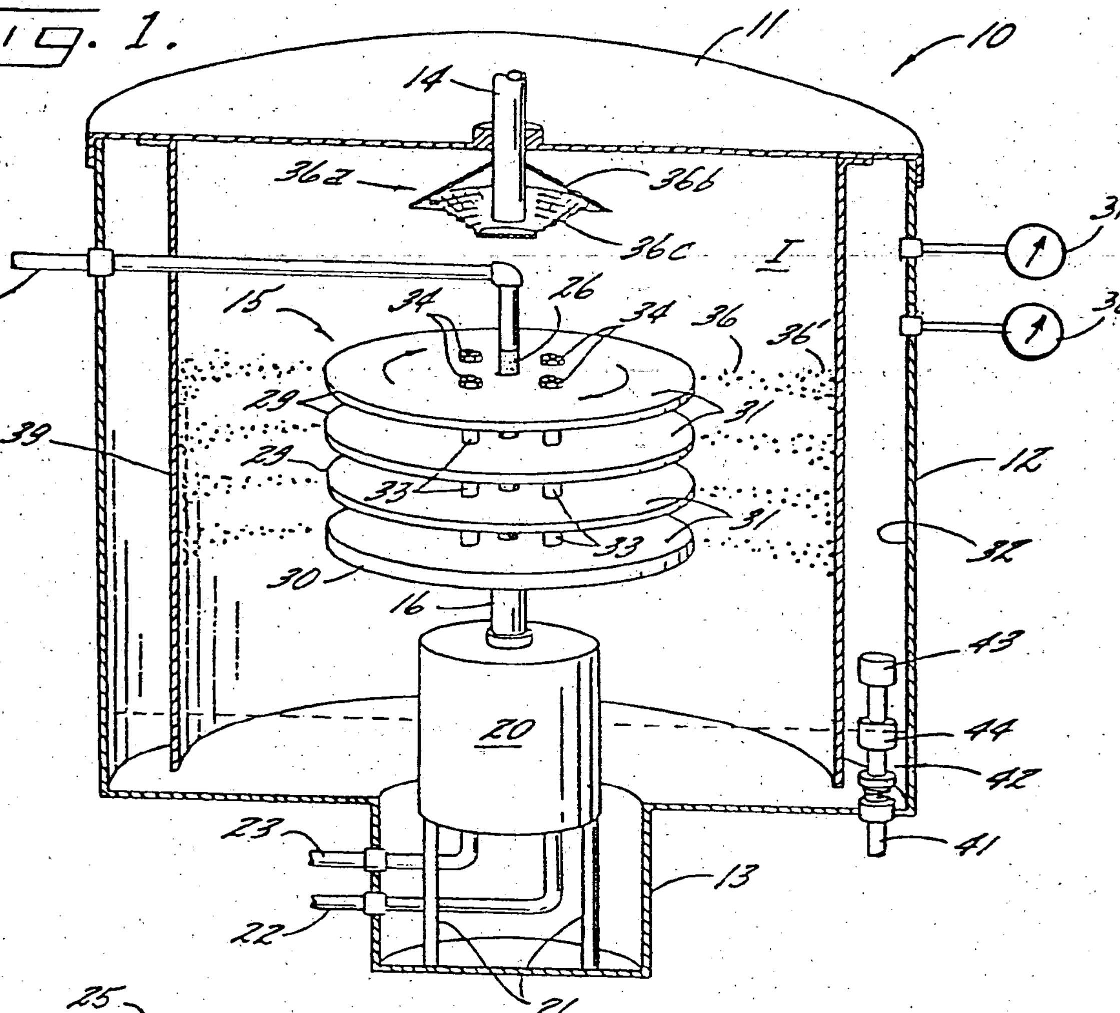
Fig. 1.



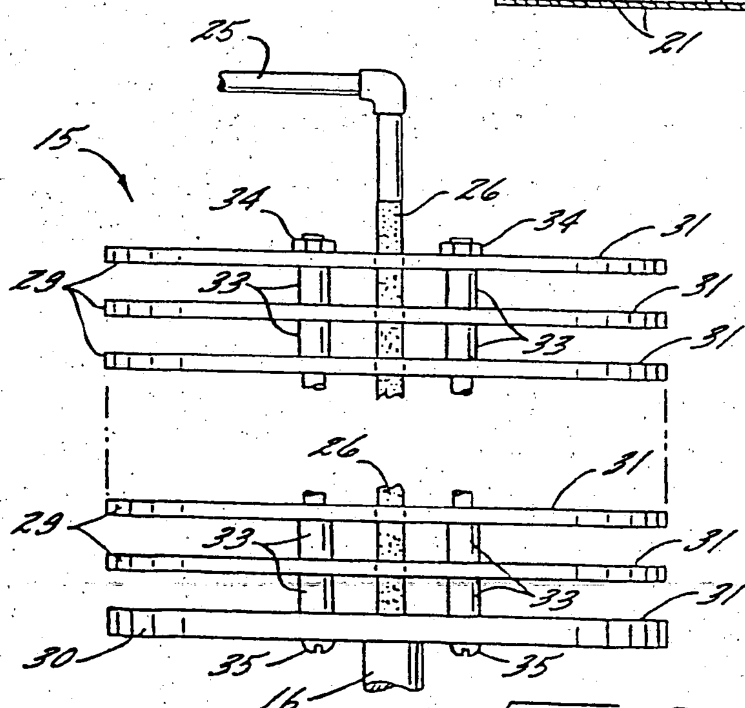


Fig. 2.

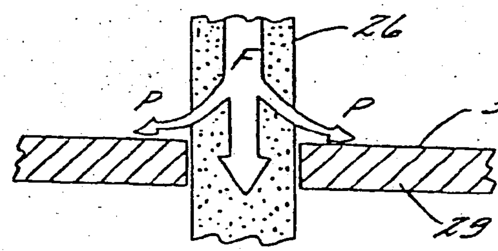


Fig. 3.

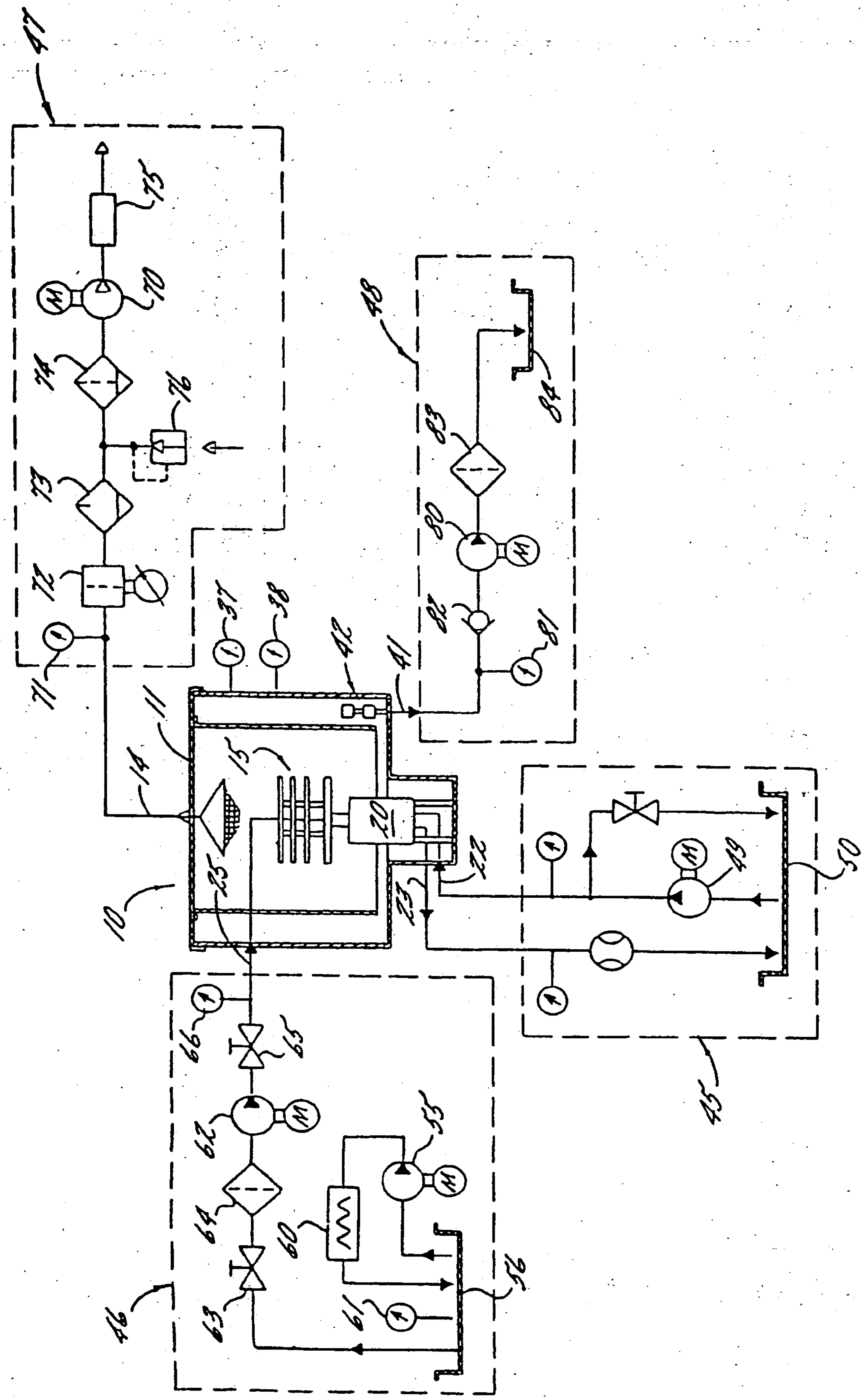


FIG. 4.

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EUROPEAN SEARCH REPORT

0141533
Application number
EP 84 30 6695

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl.4)
X	DE-C- 345 805 (METALLBANK UND METALLURGISCHE GESELLSCHAFT AG) * Page 1, lines 16-75; figures *	1-4,7-9,11-13	B 01 D 1/16 B 01 D 19/00 C 10 M 175/00 B 05 B 3/10
A	US-A-2 258 445 (W. COOPEY) * Column 2, line 57 - column 3, line 74; figures *	1-4	
A	FR-A- 581 442 (RAPPOLD & VOLK AG) * Page 3, lines 23-90; figures *	1	
A	GB-A-2 061 755 (A/S AKERS MEK) * Page 2, line 14 - page 3, line 45; figure 1 *	1,2	TECHNICAL FIELDS SEARCHED (Int. Cl.4)
A	DE-A-2 259 740 (SIEMENS AG) * Page 4, line 19 - page 6, line 11; figures 1,2 *	1,2,11,13	B 01 D C 10 M B 05 B

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	21-01-1985	VAN BELLEGHEM W.R.

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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